



Cost estimates for sMDT muon chambers WBS 6.6.y.5

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U.S. ATLAS HL-LHC Upgrade NSF Conceptual Design Review

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sMDT experts

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 - L3 manager for Phase 1 upgrade project: L1 Calorimeter trigger fiber plant
- Bing Zhou, 6.6.3.5
 - Professor, University of Michigan
 - The US ATLAS project leader for the current ATLAS MDT detector construction, commissioning and operations
 - The U of M project leader for design and construction of 32,000 tubes and 80 largest MDT chambers for the current ATLAS Muon Spectrometer



Institutes

- Michigan State University, WBS 6.6.5.5
 - Experienced electronics engineers
 - Experience in large construction projects
 - Tile calorimeter modules for ATLAS
 - Fibers for Nova neutrino experiment
 - Many others
 - Overhead rate 55% (on-campus)
 - Fringe rate about 28%
- University of Michigan, 6.6.3.5
 - Long experience in muon detection
 - Room, granite table, infrastructure in place from MDT construction
 - Overhead rate 26% (off-campus)
 - Fringe rate about 28%



ATLAS sMDT upgrade

- Total: 48,000 tubes in 96 chambers
 - Half built at MPI in Munich, Germany with help from Protvino, Russia
 - Half built in US
- WBS 6.6.5.5: tube construction
 - In a clean room in HEP area at Michigan State University
 - By MSU HEP engineers and technicians
 - 25,000 tubes, incl. 5% overage
- WBS 6.6.3.5: Tubes assembled into chambers
 - In existing facilities at University of Michigan
 - By U of M HEP engineers and technicians
 - 48 chambers assembled and tested
- Close cooperation and coordination between the two institutes



Budget estimation

- Material estimate based on previous purchases for MDT construction and on existing purchases at MPI Munich
- Engineering and technician estimate based on experience with MDT construction at University of Michigan and sMDT construction at MPI Munich

2) Labor sMDT construction

- a. Construction and test total 25000 tubes (with 5% spares) starting from April, 2020 and finish by Sept. 2022 requesting total 4.75 FTE mechanical technician support. Assuming on average constructing and test 50 tubes each day. The task will need 1.0 FTE for tube assembly and 1.0 FTE for tube tests (wire tension, leak and dark current). Faculty member will need to provide supervision for construction and testing.
- b. Construction and test total 48 sMDT chambers in 27 months starting from July 2020 and finish by Dec. 2022. All the sMDT need to be shipped to CERN by the end of 2022. Assuming on average constructing and test one chamber (gluing 8 layers of tubes and a precision spacer frame) every two weeks. In addition, the different types of spacer frames need to be designed and fabricated, as well as the gas system and HV and RO distribution boards, and the FC must be installed on chamber and perform gas leak and HV tests for each chamber. The task will need 0.5 FTE mechanical engineer, 0.5 FTE electric engineer, 2.0 FTE mechanical technician and 1.0 FTE engineer student for 27 months. Faculty member will need to provide supervision for construction and testing.

The needed labor FTEs are based on experience with the MDT tube and chamber constructions for Run 1 muon detector at the University of Michigan, as well as the sMDT construction experience at MPI (Germany) for muon detector Phase I upgrade project.

Summary Labor for sMDT construction: (total 13.75 FTE)

Total 4.75 FTE of Mechanical Technician for tube assembly and test

Total 9.0 FTE (1.125 M.E., 1.125 E.E., 4.5 M. Tech. and 2.25 E. student)



Tube construction cost

		on average build and test 50 tubes per day.
construct of 25000 tubes (with spares)		
Materials for tube assembly		
Al tubes	25000 tubes (8/tube)	200,000
Wire	1000/km	41,500
end-plug	50000 (7.2/unit)	360000
Total		601,500
other M&S for clean room		25,000
Manpower		Two FTE each year for 27 month
Mech Tech	2.0 FTE	172,579
IDC/year		94,919
Salary, benefit, IDC/year		267,498
For 27 month (2.25 year)		601,870
Travel		18000
Total cost for tube construction		1,246,370



Chamber construction cost

Chamber construction		cost for
Manpower	FTE/year	27 months
Mech Eng	0.5 FTE	157,040
Elec Eng	0.5 FTE	147,760
Mech tech	2.0 FTE	506,590
Eng student	2.0 FTE	126,650
construction manpower		938,040
M&S		
Gas connectors		90,720
Spacer/support		50,400
Faraday Cages		25,200
Gas distribution		20,160
Alignment parts		20,160
Transport tools		25,200
HV/RO distribution		228,413
Total Core cost		460,253
M&S (glue and so on)		50,000
Travel		18,000
Chamber construction		1,466,293



Risk

- Raw materials purchasing through CERN using CHF – Exchange rate fluctuations – Purchase tubes/end-plugs and so on in US?
- A lot of R&D was carried out when building the current muon MDT chambers to find qualified company who can provide high quality (tube wall thickness uniformity better than 10%, straightness better than 1%, and well defined the tube clean procedure. We tested tubes from five different companies (including one from US) worldwide and selected one from Switzerland. The same situation for end-plugs and wire locator (twister), wire-pin and O-ring.
- Identifying US companies for these specialized precision, clean tubes, end-plus (radiation hard material, no out-gassing, no cracks under tube crimping pressure) would require intensive R&D, which would cost a lot more time and funds

Labor for pre-production (tooling and model-0)

- 1) **Pre-production:** build the **tube** and **chamber** assembly and test stations and produce module-0 to certify the precision and procedure for construction tasks.
 - a. Will need labor for tube pre-construction: 1.0 FTE mechanical engineer, 1.0 FTE mechanical technician and 0.5 FTE electrical engineer for 12 months in 2019 – to build the automatic wiring station, and the wire tension, tube leak and dark current test stations
 - b. Will need labor for chamber pre-construction: 1.0 FTE mechanical engineer, 1.0 FTE mechanical technician and 1.0 FTE electrical engineer for 15 months in 2019 – 2020 – to build the automatic gluing machine, the chamber assembly precision jigging on granite table, the precision spacer assembly station, the gas assembly and test station, and electronics (HV and RO) test station. In addition, design the mechanical structure for chamber mounting and integration with RPC as well as for alignment device installation mounts.



Tube pre-construction cost

Tube tooling cost estimation	Cost	Comment -- need one year
1) Wiring table (12 feet x 4 feet)	3000	Shipping from UM
2) clean flowbox(2)	24,000	purchase
3) mechanical tube crimping device (2)	4,000	purchase
4) Wire pin crimping tool (2)	4,000	purchase
5) Auto-wiring tension system	5,000	build
6) Tension test station	3,000	build
7) Leak detector	22,000	purchase
8) dark current test station	10,000	build
9) Mech structures on wiring table	15,000	build
10) gas system for leak test (flow meters...)	10,000	build
11) module 0 tubes and parts (650 tubes)	12,000	construction
12) other M&S (cealn cloth, shoe, and pads)	8,000	purchase
Total tooling cost	120,000	
Manpower to build and test the tube assembly:		
Mech engineer (1 FTE, Shooltz)	78,020	Mech design and set up of the tooling
Elec. Engineer (0.5 FTE)	51,500	write software for auto wiring, test stations
		Assist to build the wiring stations, Mod 0 tubes, and
Mech. Tech. (1 FTE, Nila)	50,690	test them
Total manpower for tooling	180,210	
Travel	3,000	
Total cost for pre-construction	303,210	



Chamber pre-construction

(Construction tooling, one year, build/test Mod 0, 3 month, including review)					
Chamber tooling					
Set up assembly room and tables		1 month	10,000	temp./humidity control system	
Design and produce the chamber assembly jigging		3 month	40,000	design and machining (2 sets)	
Design and build the gluing machine, test		2 month	100,000	purchase/build	
Install the tooling on granite table, and measurement tool		1 month	10,000	machining	
Precision measurement tooling and test/software		1 month	50,000	Purchase	
Design and construct the chamber handle carts		2 month	10,000	build	
Design and construct the gas manifold		1 month	10,000		
design the HV test electronics boards and set up test stations		2 month	10,000		
design and construct the gas test stations		2 month	5,000	Leak detector will need to be maintained	
design and construct the cosmic ray test station		3 month	10,000		
design the shipping boxes and protocol		1 month	5,000		
Design and produce spacer frame (mod 0)		1 month	8,000		
Design and produce gas manifold, parts (mod 0)		3 month	4,000		
Design and build the gas connection parts clean bath		2 weeks	2,000		
Design and build FC (Mod)		1 month	3,000		
Build Mod 0 (with clean room M&S, glue, mixing...)			3,000		
Tooling cost			280,000		
Manpower	15 month (1.25 year)				
Mech Eng (1 FTE)	186,190				
Electric Eng (1 FTE)	15,883				
Mech Tech (1 FTE)	190,996				
Eng. Student	13,614				
manpower for tooling	406,683				



Material estimate details

- Compare to current sMDT construction for BIS 7/8 at MPI in Munich and Protvino in Russia
 - 16 chambers, each containing 900 tubes (14,400 tubes total)
 - Tubes: 8 CHF per tube
 - Gas connectors: 1,000 per chamber for 1.80 CHF each
 - Spacer-frame/support: 1,000 CHF per chamber
 - Faraday cages: 500 CHF per chamber
 - Gas distribution system: 400 CHF per chamber
 - Alignment system: 400 CHF per chamber
 - Transportation tools: 500 CHF per chamber
 - HV/RD cards: 4435 per chamber
- Basis for our estimate



Material estimate details

- Original MDT construction at University of Michigan:
 - Tube: 4.5 CHF per meter now: 8 CHF
 - End-plug: 8 CHF each now: 7.2 CHF
 - HV/RD card: 100 CHF each now: 95 CHF
 - Gas bar: \$2,000 per chamber now: \$1,000 (simpler design)
 - Faraday cage: \$2,000 per chamber now: \$500 CHF (simpler shape)
 - Spacer frame: \$3,000 per chamber now: \$1,050 (simpler design)
 - Transportation: \$20,000 *6 now: \$25,200
 - Alignment parts: \$500 per chamber now: 400 CHF
- Consistent with our estimate



Person-power estimate details

- At MPI in Munich for current sMDT construction for BIS 7/8
 - 2 technicians for tube production and tests
 - 3 technicians for chamber production and tests
 - 1 mechanical engineer
 - Several physicists and students are also contributing
- At University of Michigan for MDT construction in 2000-2003
 - Larger effort
 - MDT chambers were 4 to 6 meters long
 - 4 different types of MDT chambers
 - 2 mechanical engineers
 - 2 technicians for tube production and tests
 - 4 technicians for chamber production and tests
 - 1 technician for logistics
 - 2.5 physicists and a few students



Closing Remarks

- sMDT construction is required to enable Phase-2 muon trigger upgrades
- 25,000 tubes to be constructed at MSU
- Assembled into 48 chambers at U of M
- Cost estimate based on experience at U of M and at MPI in Munich